THE CLEMENTINE MISSION: AN ARCHIVE OF A DIGITAL IMAGE MODEL OF THE MOON; Chris E. Isbell, Eric M. Eliason, Tammy Becker, Ella M. Lee, U.S. Geological Survey, 2255 N. Gemini Drive Flagstaff, AZ 86001; Alfred McEwen, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; and Mark Robinson, Northwestern University, Dept. Geol. Sciences, Evanston, IL. 60205

Summary

A global Digital Image Model (DIM) [1] of the Moon containing controlled image mosaics has been compiled by the U.S. Geological Survey for distribution through Internet services and CD-ROM optical disk media. This database is the product of an exhaustive lunar cartography project based on data from the Clementine Mission [2]. The Lunar DIM is a radiometrically and geometrically controlled, photometrically modeled global image mosaic at a resolution of 100 meters per pixel. The Lunar DIM is initially distributed as a mono-spectral dataset using images from the 750-nm filter observations of the UVVIS camera. Current project work will produce a multi-spectral Lunar DIM containing the full complement of 11 spectral bands available from the Clementine Mission. The mono-spectral Lunar DIM, organized on 15 volumes and available through the Planetary Data System Imaging Node, is expected to provide support not only for primary lunar science investigators but also for the scientific and engineering operations of future expeditions to the Moon.

Introduction

The Clementine Mission acquired nearly 1.7 million images covering virtually 100% of the lunar surface in 11 spectral bandpasses from 415 to 2792 nm and at resolutions from 80-330 meters/pixel [3]. These raw image data [3] were archived on CD-ROM by the Naval Research Laboratory (NRL) and are available from the Planetary Data System (PDS) Imaging Node [4] (http://www-pdsimage.jpl.nasa.gov/PDS/). Raw image data containing the artifacts and radiometric and geometric characteristics of unprocessed and uncorrected data require significant processing capabilities. These capabilities may not be available to most remote sensing scientists. In order to facilitate the use of the Clementine imaging data, the DIM has been created. All systematic processing steps needed to characterize the spectral properties of the data have been applied. This global DIM product, generated at a resolution of 100 meters per pixel (~303 pixels/degree), with each pixel stored as a 16-bit integer, results in a ~11 gigabyte data set. Ancillary data such as index catalog files and complete documentation are included in support of the DIM products. A graphical user interface, a Hypertext Markup Language (HTML) file, provides users with a means of easy access to the Lunar DIM and documentation files provided within the archive. The complete archive collection consist of 15 CD-ROM volumes. Our goal is to provide a valuable and useful resource to the planetary science community.

Clementine Digital Image Model

The Integrated Software for Imaging Spectrometers (ISIS) [5] processing system, developed by the U.S. Geological Survey, was used to generate the Lunar DIM. Processing within ISIS includes radiometric and geometric correction, spectral registration for image cubes, photometric normalization, and image mosaicking. For Clementine data, radiometric correction involves “flat fielding,” dark current subtraction, nonlinearity correction, and conversion to radiometric units. Geometric transformations tie each raw image with the Lunar ground control network [6] and convert from raw image coordinates to DIM map projection coordinates. Photometric normalization is applied to balance brightness variations due to illumination differences between Clementine images. This is a brief summary of ISIS processing capabilities in regards to DIM generation; a more detailed description is available in [7]. Through these processes, a planetwide base map was generated using approximately 43,000 750-nm wavelength filter images acquired by the Clementine Ultra-Violet Visible (UVVIS) Camera. If the resulting 100-meter/pixel DIM of the Moon were presented as a single file, it would constitute an image of approximately 110,000 samples by 55,000 lines in cylindrical geometry, far too cumbersome for most users. The Lunar DIM has therefore been formatted in 996 sub-areas on “tiles” with nominal dimensions of 7º latitude by 6º longitude at the equator. Cartographic, digital space storage, and end user data retrieval considerations determined the archive design and tiling scheme. Current project work will allow the future release of multi-spectral Lunar DIMs containing all 11 spectral bands available from the Clementine Mission. These multi-spectral DIMs will consist of image cubes generated from image data acquired by the UVVIS (415, 750, 900, 950, 100 nm) and Near Infrared (NIR) (1100, 1250, 1500, 2000, 2600, 2780 nm) cameras.

The Clementine UVVIS 750-nm DIM is partitioned on the CD-ROM collection in the Sinusoidal Equal-Area projection as 12 “zones,” each 30º wide in longitude, and ranging from 70ºS to 70ºN latitudes (all tiles in a zone have the same center longitude of projection). Both polar regions between 70º and 90º latitudes exist as both Sinusoidal and polar stereographic projections. Each zone and each polar region exist on one archive volume. This results in a 14-volume archive set containing the full resolution (0.1

km/pixel) image model. A fifteenth volume, containing reduced-resolution planetwide coverage at 0.5, 2.5, and 12.5 km/pixel and other ancillary data, complete the archive collection. For each full- and reduced-resolution image product, a sub-sampled "browse" image is provided in Joint Photographic Experts Group (JPEG) format.

Each 30º zone is further divided into smaller tiles. The tiling scheme (Figure 1), basic to digital cartographic design [1], is similar in design to previous planetary DIMs, and maintains reasonably sized image products. In general, this design consists of rectangular tiles that are roughly 2100 pixels on a side. The actual tile size varies depending on the location within the design. Each tile covers ~7º in latitude. Longitude coverage ranges from ~6º for tiles in equatorial regions to ~60º near the poles (Figure 1). Polar regions (beyond 70º) are divided and tiled in both Sinusoidal and polar stereographic projections. A typical full-resolution DIM tile requires ~9 Mbytes of digital storage and may contain ~35 raw (now processed) Clementine images. Tiling schemes for reduced-resolution versions of the global DIM follow similar cartographic and digital storage guidelines. A detailed description of tiling schemes for full- and reduced-resolution products is provided as part of the archive documentation.

A universal HTML document provides MS-DOS, Macintosh, and UNIX computer system users a graphical interface to information stored on each archive volume. This document can be used by web browser software such as Netscape Navigator® or Microsoft Explorer® to view "browse" images for each image, documentation files, and other pertinent information provided on the archive.

In addition to and in support of the lunar DIM, ancillary information are provided. Documentation and index table files present detailed information that describe the data collection. Documentation files, provided in a variety of formats, describe content and background details regarding the archive. Index tables are organized as flat files; each row contains attribute information such as cartographic and geometric variables for each image product. These tables can be loaded into catalog and spreadsheet applications for use in image search and retrieval.

Tiling Scheme Representation

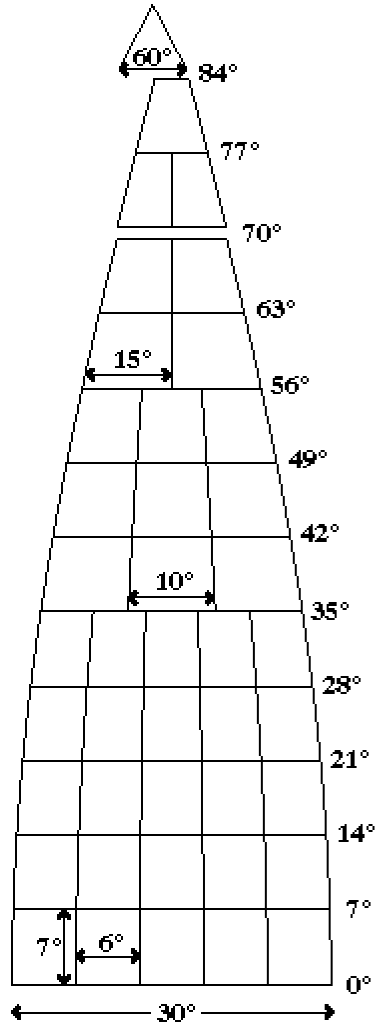

Fig. 1. This section illustrates the tiling scheme used for the 100 meter/pixel Lunar DIM. The representation is symmetric about the equator and can be repeated east and west beginning at 0º longitude.

References:

[1] Batson, R.M., 1987, Digital Cartography of the Planets: New Methods, Its Status, and Its Future. *Photogrammetric Engineering and Remote Sensing*, v. 53, no. 9, pp. 1211-1218. [2] Nozette, S., et al., 1994, The Clementine Mission to the Moon: Scientific Overview, *Science*, 266, 1835. [3] McEwen, A.S., Robinson, M.S., 1996, Mapping of the Moon by Clementine, *Advances in Space Research*. [4] Eliason, E., et al., 1995, Clementine Mission: The Archive of Image Data Products and Data Processing Capabilities, *LPSC, 26*. [5] Torson, J.M., Becker, K.J., 1997, ISIS - A Software Architecture for Processing Planetary Images, *This volume*. [6] Davies, et al., 1996, Modern Lunar Geodetic Control, *International Moon Workshop*, Berlin. [7] Eliason, E.M., 1997, Production of Digital Image Models Using the ISIS System, *This volume*.